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(54) [Title of the Invention] Organic EL Display Device and Manufacturing Method thereof

(57) [ABSTRACT]

[Object] To achieve an organic EL display device that can be manufactured with more flexibility, further allows for obtaining a wide emission wavelength range, requires a small number of wirings and a simple manufacturing process even when a complex stack structure is used such as a color display, and also allows for obtaining high luminance, and a manufacturing method thereof.

[Solving Means] An organic EL display device that is an assembly of constituent elements, the constituent element comprising at least a first electrode 2, two or more kinds of organic layers 3a and 3b each including a layer that has a light-emitting function, and a second electrode 5 in order over a substrate 1, and comprising an electrically floating intermediate electrode 4 between the organic layers 3a and 3b, and a manufacturing method thereof.

[Scope of Claims]

[Claim 1] An organic EL display device that is an assembly of constituent elements, the constituent element comprising at least a first electrode, two or more kinds of organic layers each including a layer that has a light-emitting function, and a second electrode in order over a substrate, and comprising an electrically floating intermediate electrode between the organic layers.

[Claim 2] The organic EL display device according to Claim 1, further comprising an electrode structure that has an overhang projecting in a direction parallel to a surface of the substrate and a conductive base,

wherein the constituent element is formed between the electrode structures, and the base of the electrode structure is electrically connected to the second electrode.

[Claim 3] The organic EL display device according to Claim 1 or 2, wherein the first electrode and the second electrode form a matrix structure.

[Claim 4] The organic EL display device according to Claim 2 or 3, wherein the electrode structure is formed on an insulating layer.

[Claim 5] The organic EL display device according to Claim 3 or 4, wherein the matrix structure is formed by at least a row or column element formed of the first electrode and a column or row element formed of the second electrode and the electrode structure.

[Claim 6] The organic EL display device according to any of Claims 1 to 5, further comprising an element isolation structure isolating the constituent elements.

[Claim 7] The organic EL display device according to claim 6, wherein the element isolation structure is an element isolation structure that has an overhang projecting in a direction parallel to a surface of the substrate and an insulating base.

[Claim 8] The organic EL display device according to claim 6, wherein the element isolation structure is a trench structure that is formed in the substrate or in an insulating foundation layer on the substrate.

[Claim 9] The organic EL display device according to claim 6, wherein the element isolation structure is an insulating film that is formed on a portion of the

electrode structure.

[Claim 10] The organic EL display device according to any of Claims 1 to 9, wherein each of the organic layers has a function of emitting light of a different wavelength.

[Claim 11] The organic EL display device according to any of Claims 1 to 10, wherein the film thickness of the intermediate electrode is 1 to 50 nm.

[Claim 12] A method for manufacturing an organic EL display device, the method comprising at least the steps of:

forming a first electrode on a substrate;

forming an insulating layer and then further forming an electrode structure that has an overhang projecting in a direction parallel to a surface of the substrate and a conductive base;

forming two or more kinds of organic layers each including a layer that has a light-emitting function and forming an electrically floating intermediate electrode between the organic layers; and

then forming a second electrode in order.

[Claim 13] The method for manufacturing an organic EL display device according to Claim 12, comprising the step of forming an element isolation structure before forming the first electrode or after forming the electrode structure.

[Claim 14] The method for manufacturing an organic EL display device according to Claim 13, wherein the intermediate electrode is deposited by a method for lower step coverage, and the organic layers and the second electrode are deposited by a method for higher step coverage than that of the intermediate electrode.

[Claim 15] The method for manufacturing an organic EL display device according to Claim 13 or 14, wherein the element isolation structure is formed after forming an insulating film on the substrate.

[Claim 16] The method for manufacturing an organic EL display device according to Claim 13 or 14, wherein the element isolation structure is a trench structure that is formed in the substrate or in an insulating foundation layer on the substrate.

[Claim 17] The method for manufacturing an organic EL display device according to Claim 13 or 14, wherein the element isolation structure is an insulating film that is formed at least on a portion of the electrode structure.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a manufacturing method for and a structure of an

organic electroluminescence display device (hereinafter, abbreviated to an organic EL display device) that is used as a display device and a light source.

[0002]

[Prior Art] Display devices using organic EL elements have the following advantages over liquid crystal displays that are currently mainstream flat panel displays.

- 1) The viewing angles are wider since the EL elements themselves emit light.
- 2) Thin Displays 2 to 3 mm in thickness are able to be easily manufactured.
- 3) The luminescent colors are more natural since no polarization plate is used.
- 4) Display is clearer and more vivid since the dynamic range in contrast is wider.
- 5) The display devices operate in a wider temperature range.
- 6) Moving images are able to be easily displayed since the response speed is 3-digit faster than that of a liquid crystal, or more.

[0003] In spite of these advantages, it has been hard for display devices using organic EL elements to arrive on the market because of the following reasons.

[0004] In general, an organic EL element is schematically composed of a stack of thin films that have three separate functions; an electrode composed of “a transparent conductive film”, “an organic layer including a light-emitting layer”, and an electrode composed of “a metal or an alloy that has a small work function”. There have been problems in manufacturing, such as that “the organic layer including a light-emitting layer” and “the metal or alloy that has a small work function” easily deteriorate due to moisture and oxygen and that “the organic layer including a light-emitting layer” dissolve easily in a solvent and is weak against heat. In other words, this is because it has been difficult, in the case of a method using water, an organic solvent, and heat, to separate or divide elements after depositing “the organic layer including a light-emitting layer” and “the metal or alloy that has a small work function”. In short, when efforts are made to manufacture an organic EL display device on the same level as a liquid display that is currently achieved, the matured semiconductor manufacturing technology or liquid crystal display manufacturing technology will not be able to be applied without modification.

[0005] Therefore, what is required is, for example, a technique that enables separation of the second electrode without exposure to the air and a technique for connecting elements to serve as each pixel by wiring.

[0006] Meanwhile, in order to achieve a color display using organic EL elements, various methods have been considered. For example, it is a common method to prepare a plurality of luminescent colors of light emitters themselves or obtain the three primary colors of blue, green, and red with the use of color filters.

[0007] As for an attempt to change the luminescent color of a light emitter itself, a color light-emitting element described in SID 96 DIGEST 185 14. 2, "Novel Transparent Organic Electroluminescent Devices", G. Gu, V. Bulovic, P. E. Burrows, S. R. Forrest, M. E. Thompson is known, where a Ag-Mg thin film and an ITO are used for an electron injecting electrode and a hole injecting electrode, respectively. The color light-emitting element (heterostructure organic light emitting devices) described there has a multilayer structure including light-emitting layers (RedEL, GreenEL, and BlueEL) 35, 39, and 43 corresponding to R, G, and B, respectively, as shown in FIG. 26, where electron injecting electrodes 36, 40, and 44, hole transporting layers 33, 38, and 42, and hole injecting electrodes 34, 37, and 41 are arranged in this stacking order for the respective light-emitting layers 35, 39, and 43. These are stacked on a substrate 31 as three stacked bodies corresponding to the three primary colors.

[0008] In order to drive these stacked bodies, predetermined power sources E1, E2, and E3 are connected between the electron injecting electrodes 36, 40, and 44 and the hole injecting electrodes 34, 37, and 41, respectively as in the example shown in the figure, and the respective layers are made emit light. In this case, since each stacked body has the layers stacked in the forward direction, each of the power source E1, E2, and E3 is also connected in series also in the same direction.

[0009] However, in such a structure, the number of stacked layers is large since a pair of electrodes, the hole injecting electrode and the electron injecting electrode, is used for each stacked body. For example, considering full-color displays in a simple matrix, an active matrix, and the like, it is necessary to not only provide a wiring structure for the three primary colors, which corresponds to a large number of pixels, but also develop a complex driving method.

[0010] There are a lot of market demands for white light emission itself, from which various colors can be easily created when a color filter or a fluorescence filter is used. Therefore, the possibility is expanded for designing displays.

[0011] As a method for emitting white light, a method of doping a single light-emitting layer with a plurality of fluorescent materials that produce luminescence of different colors and a method of stacking two or more light-emitting layers that provide different luminescent colors are easily considered. However, it has been difficult to obtain desired white light emission because it is not possible to appropriately obtain luminescence of a plurality of colors due to problems with compatibility with each fluorescent material or it is not possible to appropriately supply carriers to the respective light-emitting layers.

[0012]

[Problem to be solved by the Invention] It is an object of the present invention to achieve an organic EL display device that can be manufactured with more flexibility, further allows for obtaining a wide emission wavelength range, requires a small number of wirings and a simple manufacturing process even when a complex stack structure is used such as a color display, and also allows for obtaining high luminance, and a manufacturing method thereof.

[0013]

[Means for Solving the Problem] More specifically, the object is achieved by the following configurations.

- (1) An organic EL display device that is an assembly of constituent elements, the constituent element comprising at least a first electrode, two or more kinds of organic layers each including a layer that has a light-emitting function, and a second electrode in order over a substrate, and comprising an electrically floating intermediate electrode between the organic layers.
- (2) The organic EL display device according to the (1) described above, further comprising an electrode structure that has an overhang projecting in a direction parallel to a surface of the substrate and a conductive base, wherein the constituent element is formed between the electrode structures, and the base of the electrode structure is electrically connected to the second electrode.
- (3) The organic EL display device according to the (1) or (2) described above, wherein the first electrode and the second electrode form a matrix structure.
- (4) The organic EL display device according to the (2) or (3) described above, wherein the electrode structure is formed on an insulating layer.
- (5) The organic EL display device according to the (3) or (4) described above, wherein the matrix structure is formed by at least a row or column element formed of the first electrode and a column or row element formed of the second electrode and the electrode structure.
- (6) The organic EL display device according to any of the (1) to (5) described above, further comprising an element isolation structure isolating the constituent elements.
- (7) The organic EL display device according the (6) described above, wherein the element isolation structure is an element isolation structure that has an overhang projecting in a direction parallel to a surface of the substrate and an insulating base.
- (8) The organic EL display device according the (6) described above, wherein the element isolation structure is a trench structure that is formed in the substrate or in an insulating foundation layer on the substrate.

(9) The organic EL display device according to the (6) described above, wherein the element isolation structure is an insulating film that is formed on a portion of the electrode structure.

(10) The organic EL display device according to any of the (1) to (9) described above, wherein each of the organic layers has a function of emitting light of a different wavelength.

(11) The organic EL display device according to any of the (1) to (10) described above, wherein the film thickness of the intermediate electrode is 1 to 50 nm.

[0014] (12) A method for manufacturing an organic EL display device, the method comprising at least the steps of: forming a first electrode on a substrate; forming an insulating layer and then further forming an electrode structure that has an overhang projecting in a direction parallel to a surface of the substrate and a conductive base; forming two or more kinds of organic layers each including a layer that has a light-emitting function and forming an electrically floating intermediate electrode between the organic layers; and then forming a second electrode in order.

(13) The method for manufacturing an organic EL display device according to the (12) described above, comprising the step of forming an element isolation structure before forming the first electrode or after forming the electrode structure.

(14) The method for manufacturing an organic EL display device according to the (13) described above, wherein the intermediate electrode is deposited by a method for lower step coverage, and the organic layers and the second electrode are deposited by a method for higher step coverage than that of the intermediate electrode.

(15) The method for manufacturing an organic EL display device according to the (13) or (14) described above, wherein the element isolation structure is formed after forming an insulating film on the substrate.

(16) The method for manufacturing an organic EL display device according to the (13) or (14) described above, wherein the element isolation structure is a trench structure that is formed in the substrate or in an insulating foundation layer on the substrate.

(17) The method for manufacturing an organic EL display device according to the (13) or (14) described above, wherein the element isolation structure is an insulating film that is formed at least on a portion of the electrode structure.

[0015]

[Embodiments of the Invention] An organic EL display device of the present invention is an assembly of constituent elements including, for example, as shown in FIG. 1, at least a first electrode 2, two or more kinds of organic layers 3a and 3b each including a

layer that has a light-emitting function, and a second electrode 5 in order over a substrate 1, and including an electrically floating intermediate electrode 4 between the organic layer 3a and the organic layer 3b.

[0016] By providing the electrically floating intermediate electrode 4 between the organic layer and the organic layer, no wiring structure is made necessary for the intermediate electrode, the structure is simplified, the manufacturing process is reduced, and the cost can be reduced.

[0017] For example, as shown in FIG. 2, the stacked body, which is the constituent element, can be regarded as diodes with each organic layer as a unit. Therefore, the constituent element that has a plurality of organic layers stacked has diodes D1 to D3 connected in series as each light-emitting unit. In addition, the constituent element requires power sources (driving voltages) E1 to E3 corresponding to the respective light-emitting units D1 to D3, which supply voltages and currents required for emitting light so that each light-emitting unit emits light.

[0018] In this case, typically as shown in FIG. 2, a node N1 and a node N2 are respectively connected to a node N3 and a node N4 as shown, and the respective light-emitting units D1 to D3 are driven independently or jointly. However, an extra wiring structure is required at that rate, the stacked structure or two-dimensional or three-dimensional wiring structure is extremely complicated, and an extremely difficult manufacturing process is required. Consequently, when a floating state is provided without making the connection of the node N1 to the node N3 or the connection of the node N2 to the node N4 as shown in FIG. 3, no wiring structure is made necessary, and the film configuration and manufacturing process can be simplified. However, the power source in this case is the sum of the power sources (driving voltages) E1 to E3 corresponding to the respective light-emitting units D1 to D3.

[0019] Although the node N1 and the node N2 that serve as an intermediate electrode is floating, the electrode ensures electrical connection between the organic layers above and below the electrode. Therefore, the power sources E1 to E3 are applied to the light-emitting units D1 to D3 connected in series so that current flows to emit light. Then, when the respective light-emitting units D1 to D3 are made to emit red, green, and blue light, white light emission is obtained. In this case, the luminescent color may be adjusted by adjusting the luminance of each light-emitting unit. In addition, the obtained white light emission can be quite easily used for a full-color display device by using a color filter. It is to be noted that although the light-emitting layers (the organic layers) comprise three layers in the example described above, it is also possible to obtain white light emission by using two layers for the light-emitting layers and

adjusting the luminescent colors of each light-emitting layer.

[0020] In addition, in order to float the intermediate electrode, it is preferable to form, for example, an electrode structure 7 as shown in FIG. 1. This electrode structure 7 has at least a conductive base 7b and an overhang 7a projecting in a direction substantially parallel to the surface of the substrate, and a shade portion obtained by this overhang 7a can make the intermediate electrode floating and efficiently carry out wiring to the second electrode.

[0021] More specifically, the first electrode is formed, an insulating layer 6 is further formed thereon, and the electrode structure 7 is then formed. Then, the organic layers and the intermediate electrode are formed, and the second electrode is formed. Then, when the intermediate electrode is deposited by a method for lower step coverage while the organic layers and the second electrode are deposited by a method for higher step coverage, the organic layers and the second electrode are formed also at a base 7a portion that is the shade portion of the electrode structure 7 while the intermediate layer is not deposited there. Accordingly, the second electrode has contact with the base 7a to provide electrical connection while the intermediate electrode provides no electrical connection. Then, when the base 7a of the electrode structure is used as a wiring electrode for the second electrode 2, the wiring structure for the second electrode 2 and the electrical structure with the intermediate electrode floating can be achieved.

[0022] It is to be noted that the first electrode and the second electrode typically form a matrix structure in which the electrodes dimensionally intersect with each other, and function as electrode wirings that serve as components of rows and columns. Accordingly, the electrode structure 7 is also formed in the form of lines. However, it is necessary to electrically isolate one electrode structure sandwiching one constituent element from the next electrode structure. Therefore, it is preferable to form an element isolation structure between one electrode structure sandwiching one constituent element and the next electrode structure.

[0023] The element isolation structure may be, for example, an insulator with an overhang as described in Japanese Patent Application No. 8-147313 the inventors previously filed, or a trench structure as described in Japanese Patent Application filed on April, 15, 1998 (Serial Number: 10P123). Alternatively, the element isolation structure may be a structure that has an insulating film formed on a portion (a site other than the side sandwiching the constituent element) of the electrode structure.

[0024] The material of the base of the electrode structure is not particularly limited as long as the material is electrically conductive, and preferably has a high electric conductivity and is not easily corroded such as oxidized. However, as a metal material,

for example, the electrode layer can be a metal thin film or the like that can be easily made thick in film thickness and has small stress, such as Al. Specifically, aluminum, an aluminum-base alloy of Al and a transition metal particularly such as Sc, Nb, Zr, Hf, Nd, Ta, Cu, Si, Cr, Mo, Mn, Ni, Pd, Pt, and W, which may preferably contain the transition metal at a total of 10 at% or less, particularly 5 at% or less, and particularly 2 at% or less, and the like can be preferably cited. Aluminum has a low resistance, and provides a favorable effect when used for the base that functions as a wiring electrode. In addition, carbon, a mixture of carbon and a resin, and the like may be used. Further, if necessary, a stacked structure of an inexpensive low-resistance metal material such as Al and Al-base alloy, and of Cr or a stable conductor such as TiN may be employed.

[0025] The material of the overhang of the electrode structure may be the same as or different from the base. However, in order to form the overhang structure, it is preferable that the material of the overhang be different so that selective etching is easy. In the case of using a different material from the base, any of insulators or conductors may be used, and preferable materials include nitrides such as a titanium nitride, a molybdenum nitride, a tantalum nitride, and a chromium nitride; silicide compounds such as a cobalt silicide, a chromium silicide, a molybdenum silicide, a tungsten silicide, and a titanium silicide; metals or metal compounds such as a titanium carbide, a doped silicon carbide, and chromium; resin materials such as a resist, a polyimide, an acrylic resin, and an olefin resin; and inorganic materials such as SiO₂, SiN_x, SiON, Al₂O₃, and SOG (spin on glass) films.

[0026] The size of the electrode structure may be appropriately adjusted to an optimal size depending on the structure of an element to be designed and the number of constituent films. However, typically, the base has a width of 1 to 50 μm and a height on the order of 300 nm to 5 μm, and the overhang has a width of 2 to 100 μm and a height on the order of 100 nm to 10 μm. In addition, it is preferable that the height of the base be on the order of 1/2 to 20 times the total film thickness of the organic layers and second electrode layer, particularly on the order of 2 to 10 times the total film thickness, and that the overhang ratio of the overhang be on the order of 1/5 to 20 times the height of the base.

[0027] In order to form the electrode structure, after forming the first electrode, an insulating layer is formed thereon and patterned, and then, a layer for the base and a layer for the overhang are further deposited thereon by vapor deposition, coating, spin coating, or the like. Then, the layer for the overhang is patterned by a technique such as photolithography, and then, the layer for the base is further etched so that only the portion for the base can be overetched at this point.

[0028] The electrode structure is formed on the insulating layer. This insulating layer can be any layer as long as the layer provides insulation, such as inorganic materials deposited by sputtering or vacuum deposition, e.g. silicon oxides such as SiO_2 , silicon nitrides, and FeO ; a silicon oxide layer formed by SOG (Spin On Glass); and coating films of resin materials such as a photoresist, a polyimide, and an acrylic resin. However, since the hole injecting electrode (an electron injecting electrode in the case of a so-called inverted stack) such as an ITO, which serves as the first electrode, is present under the insulating layer, it is preferable to use a material that is able to be patterned so as not to damage the electrode during patterning into the shape of the insulating layer. Such a preferable insulating layer material can be, for example, a polyimide.

[0029] It is preferable that the insulating layer have a film thickness on the order of 50 to 750 nm. When the film thickness of the insulating layer is too thin, it is difficult to obtain advantageous effects of the present invention. In addition, when the film thickness is too thick, gaps (discontinuous portions caused at step portions, particularly a portion from an edge portion of the insulating layer toward a central portion of the light-emitting portion and the like, during or after deposition) may be caused. The insulating layer is typically formed around the hole injecting electrode.

[0030] In the case of depositing the insulating layer by sputtering, not particularly limited, RF sputtering and DC sputtering are preferable. The applied power is preferably in the range of 0.1 to 10 W/cm^2 , particularly 0.5 to 7 W/cm^2 , in the case of a DC sputtering apparatus, and it is preferable that the deposition rate be in the range of 5 to 100 nm/min, particularly 10 to 50 nm/min. In addition, in the case of RF sputtering, the apparatus is not particularly limited as long as the apparatus has a power source that can supply high frequency waves in the RF band, but the frequency and the applied power are typically 13.56 MHz and on the order of and 100 to 500 W, respectively.

[0031] The sputtering gas is not particularly limited, and inert gases such as Ar, He, Ne, Kr, and Xe, or a mixed gas of these may be used. The sputtering gas pressure is preferably 0.3 to 3.0 Pa, and more preferably on the order of 0.5 to 1.0 Pa in the case of RF sputtering. In addition, in the case of DC sputtering, the sputtering gas pressure is on the order of 0.1 to 20 Pa.

[0032] In the case of using a resin material such as a photoresist, a polyimide, and an acrylic resin, the insulating layer can be provided by normal coating, spin coating, dipping, or the like.

[0033] In a lithography process for forming the insulating layer into a predetermined pattern, typically, a resist is applied to a substrate on which the inorganic material

described above is deposited on a substrate to which a solution of an organic polymer is applied, this resist film is irradiated with electron beams, ultraviolet rays, X-ray for exposure, and then, development is carried out with an appropriate alkali solution. Then, the interlayer insulating layer is etched, and after that, the resist is removed. The film thickness of the resist film is typically on the order of 1 to 2 μm .

[0034] In other words, the resist film described above is exposed into a predetermined pattern. The light to be used for the exposure can be electron beams, ultraviolet rays, X-ray, and the like, and the irradiation may be carried out in accordance with a normal method. In addition, as for lithography, a predetermined method such as the use of a mask may be appropriately selected depending on electron beams, ultraviolet rays, or the like to be used. After that, development is carried out with the use of an alkali liquid.

[0035] After the development, the substrate is subjected to etching with the resist film remaining on the substrate as a protective film. The etching may be either wet etching using a chemical etching solution or dry etching using plasma or accelerated ions. The chemical etching solution to be used for wet etching may be appropriately selected depending on the material of the substrate, and can be $\text{H}_2\text{O} : \text{HF} : \text{CH}_3\text{COOH} = 5 : 1 : 10$, in addition, a HF solution, a mixture of $\text{NH}_4\text{F}/\text{HF}/\text{H}_2\text{O}$, and the like.

[0036] In addition, the plasma gas to be used for plasma etching that is widely used as dry etching may be appropriately selected depending on the material of an object to be processed, and can be SF_6 , CHBr_3 , CF_4 , and the like.

[0037] A specific method, conditions, and the like for the etching may be selected in the usual manner. Then, after completion of the etching, the resist film is removed.

[0038] Materials to be used for forming the base of the element isolation structure include organic resin films such as a polyimide resin and an acrylic resin, and inorganic insulating films such as SiO_2 , SiN_x , a-Si, and SOG (Spin on Glass), and a polyimide resin, SiO_2 , SOG, and the like are preferably used. It is preferable that the material to be used for forming the overhang be a photosensitive material, for example, a photoresist and a photosensitive polyimide. Alternatively, hard insulating films and semiconductor films such as SiO_2 , SiN_x , Al_2O_3 , CrO_x , a-Si, and SiC, and conductive thin films such as Cr, Ta, Mo, Ni, W, Ti, TiN, ZnO, and an ITO can be used, and photosensitive layer stacked on an insulating film or a semiconductor film can be further cited. Preferable materials are a photoresist, SiO_2 , C, Ti, and the like.

[0039] The size of the base is not particularly limited, which normally serves as the base sufficiently when the width is 1 μm or more, but it is preferable that the width be 2 μm or more, and that the height (film thickness) be 0.2 μm or more, particularly on the

order of 0.5 to 10 μm . In addition, the size of the overhang is not particularly limited, but it is normally preferable to employ a structure with an overhang length equal to or more than 1/2 of the film thickness of the base, and it is preferable that the height (film thickness) be 0.1 to 10 μm , particularly on the order of 0.2 to 5 μm . It is preferable that the combined height of these base and overhang be 1 to 20 μm , particularly on the order of 0.7 to 10 μm .

[0040] In order to form the element isolation structure, a base layer composed of the above-mentioned material for the base is first formed on the substrate that has the hole injecting electrode, the insulating layer, and the like formed thereon, preferably by spin coating or roll coating in the case of a resin film or an SOG film, by sputtering or CVD in the case of an insulating film or a semiconductor film, or by deposition in the case of a metal compound film. Further, in the same way as described above, a photosensitive overhang layer is formed on the base layer. At the same time as or after patterning of this overhang layer by exposure and development, the base layer may be etched, and overetched so that this base layer is smaller than the overhang layer, thereby resulting in an overhang body. In the case of using sputtering for the formation of the base, the conditions and the like are the same as in the case of the interlayer insulating layer described above. In addition, the forming method for the case of forming the base or the overhang with the use of a resin or the like may conform to the technique for the photoresist described above.

[0041] In the case where the element isolation structure is a trench structure, the structure may be formed directly in the substrate, or may be formed in a foundation layer that is formed on the substrate to have a predetermined film thickness. The size of the trench structure is not particularly limited as long as element isolation is possible, and may be appropriately determined depending on the size of the display device, the size of the organic EL element to be isolated, the film thickness and deposition method of each layer that is deposited, and the like. Specifically, the width of the trench structure is typically 1 to 20 μm , particularly on the order of 5 to 10 μm , and the depth thereof is typically 1/2 to 20 times the total film thickness of the organic layers and second electrode layer, particularly on the order of 2 to 10 times.

[0042] It is preferable that this foundation layer be formed with the use of an insulating material that can be etched and provide no interference with the first electrode layer that is deposited thereon. The foundation layer for forming the trench structure may be formed with the use of a photosensitive insulating material, which can be specifically a resin material such as polyimides, acrylic resins, and olefin resins, and an inorganic material such as SiO_2 , SiN_x , SiON , Al_2O_3 , and an SOG (spin on glass) film. The

foundation layer may be formed by preferred means selected from known deposition means, such as deposition, sputtering, coating, printing, or spin coating, depending on the material to be used.

[0043] The trench structure may be formed as a mere U-shaped concave portion, may have a shape widened toward the vicinity of an opening portion, or may have a shape widened contrary toward the bottom. Such a taper angle is not particularly limited, but is preferably on the order of ± 30 to 60 degrees, particularly ± 45 degrees with respect to the opening direction (the direction perpendicular to the substrate). In addition, the trench structure may have, near the opening portion, an overhang overhanging toward the center of the trench structure in a direction substantially parallel to the substrate, or a structure projecting in a direction perpendicular to the surface of the substrate (upward) from the bottom.

[0044] Further, the element isolation structure may be a structure that has an insulating film formed on a portion (a site other than the side sandwiching the constituent element) of the electrode structure described above. In this case, after forming the electrode structure, an insulating film of a resist material may be formed at a predetermined site by depositing the photoresist material and carrying out exposure from the above and from an angle so that the resist material remains at the desired site. Alternatively, after forming an insulating film composed of a resin material such as polyimides, acrylic resins, and olefin resins, or an inorganic material such as SiO_2 , SiN_x , SiON , Al_2O_3 , and an SOG (spin on glass) film, and then, further applying a photoresist, exposure and development may be carried out so that the insulating film remains only at a site requiring an element isolation structure.

[0045] It is preferable that the intermediate electrode be a transparent or semi-transparent electrode since it is normally required to transmit emitted light. Although transparent electrodes include an ITO (tin-doped indium oxide), an IZO (zinc-doped indium oxide), ZnO , SnO_2 , In_2O_3 , and the like, an ITO (tin-doped indium oxide) and an IZO (zinc-doped indium oxide) are preferable. Although the ITO typically contains a stoichiometric composition of In_2O_3 and SnO , the amount of O may be somewhat out of this composition. It is preferable that the mixture ratio of SnO_2 to In_2O_3 be 1 to 20 wt%, and more preferably 5 to 12 wt%. In addition, the mixture ratio of ZnO_2 with respect to In_2O_3 in the IZO is typically on the order of 12 to 32 wt%.

[0046] It is preferable that the intermediate electrode have a light transmission of 60 % or more, preferably 80 % or more, and particularly 90 % or more with respect to an emission wavelength band, typically 350 to 800 nm, particularly with respect to each emitted light. The emitted light is normally extracted through the intermediate

electrode. Therefore, when the transmission is decreased, light emission itself from the light-emitting layer is attenuated, and the luminance required for the light-emitting element tends to be unable to be obtained.

[0047] The following metal materials can be also used for the intermediate electrode as long as the materials can ensure the light transmission described above. In this case, a material that has a small work function is preferable, and for example, it is preferable to use a metal element such as K, Li, Na, Mg, La, Ce, Ca, Sr, Ba, Al, Ag, In, Sn, Zn, and Zr, or to use a two-component or three-component alloy containing those elements for improving the stability. As the alloy, for example, Ag:Mg (Ag: 0.1 to 50 at%), Al:Li (Li: 0.01 to 14 at%), In:Mg (Mg: 50 to 80 wt%), Al:Ca (Ca: 0.01 to 20 at%), and the like are preferable. In addition, it is particularly preferable to use oxides of these alloys. When an oxide such as an ITO is used for the first electrode, the use of the oxide as the intermediate electrode makes the pair of oxides surround the organic layer to improve the weather resistance.

[0048] The intermediate electrode may have a certain thickness or more that can separate the organic layers from each other and ensure injection and transport of electrons and holes, and preferably has a thickness in the range of 1 to 50 nm, more preferably 5 to 20 nm. In addition, the upper limit of the thickness is not particularly limited. However, when the intermediate electrode is too thick, there is concern such as that the light transmission may be decreased and the intermediate electrode may be separated. When the intermediate electrode is too thin, the intermediate electrode has a problem in terms of film strength.

[0049] This intermediate electrode can be formed by either deposition or sputtering.

[0050] It is to be noted that, for the organic layers in contact with the intermediate electrode, it is preferable to appropriately select and use organics to be described, and more preferably, electron injecting or hole transporting materials that are compatible with these electrode materials instead of or in addition to the organics. As the organics, for example, polythiophene, copper phthalocyanine and the like are cited.

[0051] The first electrode typically function as a hole injecting electrode. It is preferable that the first electrode be a transparent or semi-transparent electrode similarly to the intermediate electrode since emitted light is typically extracted from the substrate side. The transparent electrode can be an ITO, an IZO, ZnO, SnO₂, In₂O₃, or the like, and is preferably an ITO or an IZO.

[0052] The hole injecting electrode, when used as a hole injecting electrode, may have a certain thickness or more that can carry out hole injection sufficiently, and preferably has a thickness in the range of 10 to 500 nm, more preferably 30 to 300 nm. In

addition, the upper limit of the thickness is not particularly limited. However, when the hole injecting electrode is too thick, degradation of workability, failure due to stress, decrease in light transmission, leakage due to surface roughness, and the like are caused. Contrary, when the hole injecting electrode is too thin, the hole injecting electrode has problems in terms of film strength in manufacturing, hole transport ability, and resistance value.

[0053] The first electrode can be formed by either deposition or sputtering, and sputtering (pulse DC sputtering) is preferable particularly in the case of an ITO and the like.

[0054] The second electrode typically function as an electron injecting electrode. As the electro injecting electrode, a material that has a low work function is preferable, and can be the examples given as the intermediate electrode described above, and the like. It is to be noted that the electron injecting electrode can be formed by deposition or sputtering.

[0055] The electron injecting electrode thin film may have a certain thickness or more that can carry out electron injection sufficiently, and may have a thickness of 0.1 nm or more, and preferably 0.5 nm or more, particularly 1 nm or more. In addition, the upper limit of the thickness is not particularly limited, but the film thickness may be typically on the order of 1 to 500 nm. For the electron injecting electrode, an auxiliary electrode may be further provided.

[0056] The auxiliary electrode may have a certain thickness or more to ensure an electron injection efficiency and prevent moisture, oxygen, or an organic solvent from entering, and preferably has a thickness of 50 nm or more, and more preferably 100 nm or more, particularly in the range of 100 to 1000 nm. When the auxiliary electrode is too thin, the effect thereof is not obtained, and the step coverage of the auxiliary electrode is decreased to result in an insufficient connection with a terminal electrode. On the other hand, when the auxiliary electrode is too thick, the growth rate of a dark spot is increased since the stress of the auxiliary electrode is increased.

[0057] The total thickness of the electron injecting electrode and protective electrode is not particularly limited, and may be typically on the order of 100 to 1000 nm.

[0058] It is to be noted that a so-called inverted stacked structure may be employed which has the first electrode as an electron injecting electrode and the second electrode as a hole injecting electrode.

[0059] After depositing the electrode, a protective film using an inorganic material such as SiO₂, an organic material such as teflon or a carbon-fluoride polymer containing chlorine, or the like may be formed in addition to the protective electrode described

above. The protective film may be transparent or non-transparent, and has a thickness on the order of 50 to 1200 nm. The protective film may be formed by the reactive sputtering described above, or by general sputtering, deposition, PECVD, or the like

[0060] Next, the organic layers to serve as each light-emitting unit of the constituent element will be described.

[0061] The light-emitting layer has the functions of injecting holes and electrons, of transporting them, and of generating an exciton by recombination of a hole and an electron. Electrons and holes can be injected and transported easily in a balanced manner by using a relatively electronically neutral compound for the light-emitting element.

[0062] The hole injecting and transporting layer has the functions of facilitating hole injection from the hole injecting electrode, of transporting holes stably, and of blocking electrons, while the electron injecting and transporting layer has the functions of facilitating electron injection from the cathode electrode, of transporting electrons stably, and of blocking holes. These layers increase and keep holes and electrons to be injected into the light-emitting layer, optimize the recombination region, and improve the luminous efficiency.

[0063] The thicknesses of the light-emitting layer, the hole injecting and transporting layer, and the electron injecting and transporting layer are not particularly limited. Depending on the forming methods, the thicknesses are typically on the order of 5 to 500 nm, and in particular, it is preferable that the thicknesses be made to be 10 to 300 nm.

[0064] The thicknesses of the hole injecting and transporting layer and the electron injecting and transporting layer may be equal to or on the order of 1/10 to 10 times the thickness of the light-emitting layer depending on the design of the recombination/light emission region. In the case of forming an injecting layer and a transporting layer separately each of for holes and for electrons, it is preferable that the injecting layer be made to be 1 nm or more and the transporting layer be made to be 1 nm or more. The upper limits of the thicknesses of the injecting layer and the transporting layer in this case are typically on the order of 500 nm for the injecting layer and on the order of 500 nm for the transporting layer. These film thicknesses are the same in the case of providing two injecting and transporting layers.

[0065] The light-emitting layer of the organic EL element is made to contain a fluorescent material serving as a compound that has a light-emitting function. Such a fluorescent material can be, for example, a compound as disclosed in Japanese Patent Laid-Open No. 63-264692, e.g. at least one kind selected from compounds such as

quinacridone, rubrene, and styryl dyes, and can be a quinoline derivative such as a metal complex dye having 8-quinolinol such as tris(8-quinolinolato)aluminum or a derivative thereof as a ligand, tetraphenylbutadiene, anthracene, perylene, coronene, a 12-phthaloperynone derivative, and the like. Further, phenylanthracene derivatives in Japanese Patent Application No. 6-110569, tetraarylethene derivatives in Japanese Patent Application No. 6-114456, and the like can be used.

[0066] In addition, it is preferable to use the fluorescent compound as a dopant in combination with a host material that is capable of emitting light by itself. In such a case, it is preferable that the content of the compound in the light-emitting layer be 0.01 to 10 wt%, and more preferably 0.1 to 5 wt%. The use of the compound in combination with the host material makes it possible to change the emission wavelength characteristics of the host material to enable light emission shifted to a longer wavelength and improve the luminous efficiency and stability of the element.

[0067] As the host material, quinolinolato complexes are preferable, and aluminum complexes with 8-quinolinol or a derivative thereof as a ligand are more preferable. Such aluminum complexes can include complexes disclosed in Japanese Patent Laid-Opens No. 63-264692, No. 3-255190, No. 5-70733, No. 5-258859, No. 6-215874, and the like.

[0068] Specific examples first include tris(8-quinolinolato)aluminum, bis(8-quinolinolato)magnesium, bis(benzo{f}-8-quinolinolato)zinc, a bis(2-methyl-8-quinolinolato)aluminum oxide, tris(8-quinolinolato)indium, tris(5-methyl-8-quinolinolato)aluminum, 8-quinolinolato lithium, tris(5-chloro-8-quinolinolato)gallium, bis(5-chloro-8-quinolinolato)calcium, 5,7-dichloro-8-quinolinolato aluminum, tris(5,7-dibromo-8-hydroxyquinolinolato)aluminum, poly[zinc(II)-bis(8-hydroxy-5-quinolynyl)methane], and the like.

[0069] Further, in addition to 8-quinolinol and derivatives thereof, aluminum complexes having other ligands may be used, and such aluminum complexes include bis(2-methyl-8-quinolinolato)(phenolato)aluminum(III), bis(2-methyl-8-quinolinolato)(ortho-cresolato)aluminum(III), bis(2-methyl-8-quinolinolato)(meta-cresolato)aluminum(III), bis(2-methyl-8-quinolinolato)(para-cresolato)aluminum(III), bis(2-methyl-8-quinolinolato)(ortho-phenylphenolato)aluminum(III), bis(2-methyl-8-quinolinolato)(meta-phenylphenolato)aluminum(III), bis(2-methyl-8-quinolinolato)(para-phenylphenolato)aluminum(III), bis(2-methyl-8-quinolinolato)(2,3-dimethylphenolato)aluminum(III),

bis(2-methyl-8-quinolinolato)(2,6-dimethylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(3,4-dimethylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(3,5-dimethylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(3,5-di-tert-butylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(2,6-diphenylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(2,4,6-triphenylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(2,3,6-trimethylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(2,3,5,6-tetramethylphenolato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(1-naphtholato)aluminum(III),
 bis(2-methyl-8-quinolinolato)(2-naphtholato)aluminum(III),
 bis(2,4-dimethyl-8-quinolinolato)(ortho-phenylphenolato)aluminum(III),
 bis(2,4-dimethyl-8-quinolinolato)(para-phenylphenolato)aluminum(III),
 bis(2,4-dimethyl-8-quinolinolato)(meta-phenylphenolato)aluminum(III),
 bis(2,4-dimethyl-8-quinolinolato)(3,5-dimethylphenolato)aluminum(III),
 bis(2,4-dimethyl-8-quinolinolato)(3,5-di-tert-butylphenolato)aluminum(III),
 bis(2-methyl-4-ethyl-8-quinolinolato)(para-cresolato)aluminum(III),
 bis(2-methyl-4-methoxy-8-quinolinolato)(para-phenylphenolato)aluminum(III),
 bis(2-methyl-5-cyano-8-quinolinolato)(ortho-cresolato)aluminum(III),
 bis(2-methyl-6-trifluoromethyl-8-quinolinolato)(2-naphtholato)aluminum(III), and the like.

[0070] In addition to these,
 bis(2-methyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(2-methyl-8-quinolinolato)aluminum(III),
 bis(2,4-dimethyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(2,4-dimethyl-8-quinolinolato)aluminum(III),
 bis(4-ethyl-2-methyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(4-ethyl-2-methyl-8-quinolinolato)aluminum(III),
 bis(2-methyl-4-methoxyquinolinolato)aluminum(III)- μ -oxo-bis(2-methyl-4-methoxyquinolinolato)aluminum(III),
 bis(5-cyano-2-methyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(5-cyano-2-methyl-8-quinolinolato)aluminum(III),
 bis(2-methyl-5-trifluoromethyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(2-methyl-5-trifluoromethyl-8-quinolinolato)aluminum(III), and the like may be used.

[0071] Other preferable host materials include phenylanthracene derivatives mentioned in Japanese Patent Application No. 6-110569, tetraarylethene derivatives mentioned in Japanese Patent Application No. 6-114456, and the like.

[0072] The light-emitting layer may double as the electron injecting and transporting layer, and in this case, it is preferable to use tris(8-quinolinolato)aluminum or the like. These fluorescent materials may be deposited.

[0073] In addition, it is also preferable to use a mixed layer of at least one kind of hole injecting and transporting compound and at least one kind of electron injecting and transporting compound, if necessary, and it is further preferable that a dopant be included in this mixed layer. It is preferable that the content of the compound in such a mixed layer be made to be 0.01 to 20 wt%, and more preferably 0.1 to 15 wt%.

[0074] The mixed layer has the advantage that the organic compounds are less likely to be damaged to result in an extended element life because each carrier moves through an advantageous material in terms of polarity while carriers with the opposite polarity are less likely to be injected, since a hopping conduction path for carriers is formed in the mixed layer. In addition, the above-described dopant contained in such a mixed layer makes it possible to change the emission wavelength characteristics of the mixed layer itself and shift the emission wavelength to a longer wavelength, and also makes it possible to enhance the emission intensity and improve the stability of the element.

[0075] The hole injecting and transporting compound and the electron injecting and transporting compound that are used for the mixed layer may be selected from among after-mentioned compounds for the hole injecting and transporting layer and for the electron injecting and transporting layer, respectively. Among them, as a compound for the hole injecting and transporting layer, it is preferable to use an amine derivative with strong fluorescence, for example, a triphenyldiamine derivative that is a hole transporting material, and, it is more preferable to use a styrylamine derivative or an amine derivative having an aromatic fused ring.

[0076] As the electron injecting and transporting compound, it is preferable to use a quinoline derivative, and more preferable to use a metal complex with 8-quinolinol or a derivative thereof as a ligand, particularly tris(8-quinolinolato)aluminum (Alq₃). In addition, it is also preferable to use the phenylanthracene derivative and tetraarylethene derivative mentioned above.

[0077] As the hole injecting and transporting compound, it is preferable to use an amine derivative with strong fluorescence, for example, a triphenyldiamine derivative that is the hole transporting material mentioned above, and it is more preferable to use a styrylamine derivative or an amine derivative having an aromatic condensed ring.

[0078] As for the mixture ratio in this case, depending on the mobility and concentration of each carrier, it is preferable in general that the weight ratio of the hole injecting and transporting compound / the electron injecting and transporting compound be made to

be 1/99 to 99/1, more preferably 10/90 to 90/10, and particularly preferably on the order of 20/80 to 80/20.

[0079] In addition, it is preferable that the thickness of the mixed layer be made to be a thickness corresponding to one molecular layer or more, and less than the film thickness of the organic compound layer. Specifically, it is preferable that the thickness of the mixed layer be made to be 1 to 85 nm, and more preferably 5 to 60 nm, particularly 5 to 50 nm.

[0080] In addition, as a method for forming the mixed layer, co-deposition of carrying out evaporation from different deposition sources is preferable. However, in the case of nearly equal or pretty close vapor pressures (evaporation temperatures), the compounds can also be mixed in the same deposition boat in advance, and then deposited. Although it is more preferable that the compounds are uniformly mixed with each other in the mixed layer, in some cases, the compounds may be present in island shapes. The light-emitting layer is formed to have a predetermined thickness, typically by depositing an organic fluorescent material or carrying out coating of an organic fluorescent material dispersed in a resin binder.

[0081] In addition, for the hole injecting and transporting layer, for example, various organic compounds mentioned in Japanese Patent Laid-Opens No. 63-295695, No. 2-191694, No. 3-792, No. 5-234681, No. 5-239455, No. 5-299174, No. 7-126225, No. 7-126226, No. 8-100172, EP0650955A1, and the like can be used, which include for example, tetraarylbenzidine compounds (triaryldiamines or triphenyldiamines: TPD), aromatic tertiary amines, hydrazone derivatives, carbazole derivatives, triazole derivatives, imidazole derivatives, oxadiazole derivatives having an amino group, polythiophenes, and the like. From among these compounds, only one kind of material compound may be used, or two or more kinds of compounds may be used together. In the case of using two or more kinds of compounds, separate layers of the compounds may be stacked, or the compounds may be mixed.

[0082] In the case of providing separate hole injecting and hole transporting layers as the hole injecting and transporting layer, a preferable combination can be selected and used among from the compounds for the hole injecting and transporting layer. In this case, it is preferable to stack the compounds in ascending order of ionization potential from the hole injecting electrode (an ITO or the like) side. In addition, it is preferable that a compound that can be made into a favorable thin film be used for the surface of the hole injecting electrode. Such a stacking order is also the same in the case of providing two or more hole injecting and transporting layers. Such a stacking order makes it possible to reduce the driving voltage, and prevent generation of leak current

and generation and growth of dark spots. In addition, in the case of an element to be made, a thin film on the order of 1 to 10 nm can also be made uniform and pin-hole free due to the use of deposition. Therefore, even when a compound that has a small ionization potential and absorbs visible light is used for the hole injecting layer, change in hue of the luminescent color and decrease in the efficiency due to reabsorption can be prevented. The hole injecting and transporting layer can be formed by depositing the compound mentioned above in the same way as the light-emitting layer.

[0083] In addition, for the electron injecting and transporting layer that is provided if necessary, quinoline derivatives such as an organic metal complex having 8-quinolinol or a derivative thereof as a ligand, e.g. tris(8-quinolinolato)aluminum, oxadiazole derivatives, perylene derivatives, pyridine derivatives, pyrimidine derivatives, quinoxaline derivatives, diphenylquinone derivatives, nitro-substituted fluorene derivatives, and the like can be used. The electron injecting and transporting layer may double as the light-emitting layer, and in this case, it is preferable to use tris(8-quinolinolato)aluminum and the like. The electron injecting and transporting layer may be formed by deposition or the like in a similar way to the light-emitting layer.

[0084] In the case of stacking separate electron injecting and electron transporting layers as the electron injecting and transporting layer, a preferable combination can be selected and used from among the compounds for the electron injecting and transporting layer. In this case, it is preferable to stack the compounds in descending order of electron affinity value from the electron injecting electrode side. Such a stacking order is also the same in the case of providing two or more electron injecting and transporting layers.

[0085] It is preferable to use vacuum deposition for forming the hole injecting and transporting layer, the light-emitting layer, and the electron injecting and transporting layer because a homogeneous thin film can be formed. When vacuum deposition is used, a homogeneous thin film that is amorphous or has a crystal grain size of 0.1 μm or less is obtained. When the crystal grain size is over 0.1 μm , non-uniform light is emitted, the driving voltage of the element has to be increased, and the hole injection efficiency is also significantly decreased.

[0086] The conditions for the vacuum deposition are not particularly limited, but it is preferable that vacuum be made to be 10^{-4} Pa or less, and the deposition rate be made to be on the order of 0.01 to 1 nm/sec. In addition, it is preferable that the respective layers be continuously formed in vacuum. When the layers are continuously formed in vacuum, impurities can be prevented from adsorbing to the interfaces between the

respective layers, and high characteristics are thus obtained. Further, the driving voltage of the element can be made lower, and generation and growth of dark spots can be suppressed.

[0087] In the case of using vacuum deposition for forming the respective layers, when one layer is made to include a plurality of compounds, it is preferable to carry out co-deposition by individually controlling the temperatures of respective boats with the compounds therein.

[0088] In the present invention, the respective light-emitting units are inside connected in series. Therefore, it is difficult to electrically control light emission of each light-emitting unit. In general, the obtained luminescent color is white or a single luminescent color obtained by adjusting and combining the luminance of each light-emitting unit. Thus, it is desired to obtain full color or any luminescent color in a portion thereof, a color filter may be used to adjust the luminescent color.

[0089] In this case, a color filter film, a color conversion film containing a fluorescent material, or a dielectric reflective film may be used for the substrate to control the luminescent color.

[0090] For the color filter film, color filters that are used in liquid crystal displays and the like may be used. The characteristics of a color filter may be adjusted in accordance with light emitted by the organic EL element to optimize the extract efficiency and the color purity.

[0091] Alternatively, when a color filter that is capable of cutting out outside light of short wavelengths, which is absorbed by an EL element material or a fluorescent conversion layer, is used, the light resistance of the element and the contrast of the display are also improved.

[0092] Alternatively, an optical thin film such as a dielectric multi-layer film may be used instead of a color filter.

[0093] A fluorescent conversion filter film performs color conversion of a luminescent color by absorbing light of electroluminescence and emitting light from the fluorescent material in the fluorescent conversion film, and is formed by the composition of three materials, a binder, a fluorescent material, and a light absorbing material.

[0094] As the fluorescent material, a material that has a high fluorescence quantum efficiency may be used basically, and it is desirable that the material exhibit strong absorption of the EL wavelength range. In practice, laser dyes and the like are preferable, and rhodamine compounds, perylene compounds, cyanine compounds, phthalocyanine compounds (also including subphthalocyanine compounds and the like), naphthaloimide compounds, condensed ring hydrocarbon compounds, condensed

heterocyclic compounds, styryl compounds, coumarin compounds, and the like may be used.

[0095] For the binder, a material may be selected basically so that quenching of fluorescence is not caused, and a material that can be subjected to fine patterning by photolithography or printing is preferable. In addition, in the case of forming the binder on the substrate to have contact with the hole injecting electrode, a material that is not damaged during deposition of an ITO or an IZO is preferable.

[0096] The light absorbing material is used when light absorption by the fluorescent material is insufficient, and can be omitted if not necessary. In addition, for the light absorbing material, a material may be selected so that quenching of fluorescence from the fluorescent material is not caused.

[0097] Further, in order to prevent the organic layers and electrodes of the element from being oxidized, it is preferable to form a sealing layer on the element. For the sealing layer, in order to prevent moisture from entering, a sealing plate is bonded with the use of an adhesive resin layer to carry out hermetic sealing. An inert gas such as Ar, He, and N₂ is preferable for the sealing gas. In addition, it is preferable that the water content of this sealing gas be 100 ppm or less, more preferably 10 ppm or less, and particularly 1 ppm or less. This water content has no particular lower limit, but is typically on the order of 0.1 ppm.

[0098] The material of the sealing plate, which is preferably flat, can be a transparent or semi-transparent material such as glass, quartz, and resin and in particular, glass is preferable. As such a glass material, alkali glass is preferable in terms of cost, and in addition to this, glass compositions such as soda lime glass, lead-alkali glass, borosilicate glass, aluminosilicate glass, and silica glass are also preferable. In particular, a glass material of soda glass without surface treatment, which is inexpensively used, is preferable. As the sealing plate, besides glass plates, metal plates, plastic plates, and the like can be also used.

[0099] The sealing plate may be kept at a desired level by using a spacer to adjust the level of the sealing plate. The material for the spacer can be resin beads, silica beads, glass beads, glass fibers, and the like, and in particular, glass beads and the like are preferable. The spacer is typically grains that have a uniform grain size. However, the shape thereof is not particularly limited, and various shapes may be employed as long as the spacer function without trouble. As for the size, it is preferable that the diameter in terms of circle be 1 to 20 μm , more preferably 1 to 10 μm , and particularly 2 to 8 μm . It is preferable that a spacer with such a diameter have a grain length on the order of 10 μm or less, and the lower limit thereof, which is not particularly restricted, is

typically equal to or more than the diameter.

[0100] It is to be noted that a spacer may be used or need not be used when the sealing plate has a concave portion formed. In the case of using a spacer, the preferable size is in the range mentioned above, and in particular, the range of 2 to 8 μm is preferable.

[0101] The spacer may be in advance mixed in the adhesive agent for sealing, or may be mixed at the time of adhesion. The spacer content in an adhesive agent for sealing is preferably 0.01 to 30 wt%, and more preferably 0.1 to 5 wt%.

[0102] The adhesive agent is not particularly limited as long as a stable adhesive strength is kept and favorable airtightness is provided. However, it is preferable to use a cation-curable type ultraviolet curable epoxy resin adhesive.

[0103] The substrate material is not particularly limited, and can be determined appropriately depending on the material for the electrode of the organic EL structure to be stacked. For example, the substrate material may be a metal material such as Al, or a transparent or semi-transparent material such as glass, quartz, and resin, or may be non-transparent. In this case, in addition to glass and the like, ceramics such as alumina, metal sheets such as stainless steel which are subjected to insulating treatment such as surface oxidation, thermosetting resins such as a phenol resin, thermoplastic resins such as a polycarbonate, and the like can be used. For the organic EL display device of the present invention, pulse driving and direct current driving are typically used, and alternate driving can be also used. The driving voltage is typically on the order of 2 to 30 V.

[0104]

[Examples] Next, preferred examples of the present invention will be described with reference to the drawings.

<Example 1> First, as shown in FIGS. 4 and 5, an ITO (tin-doped indium oxide) was deposited by sputtering to be 100 nm as the first electrode 2, where FIG. 4 is a plan view and FIG. 5 is a fragmentary cross-section view of FIG. 4 along the line A-A'. The ITO was patterned by photolithography to have a stripe pattern. Etching was carried out with the use of an etching solution that has a mixture ratio of $\text{HCl} : \text{HNO}_3 : \text{H}_2\text{O} = 6 : 1 : 19$. When the resist was separated, a pattern was formed as shown in FIG. 4.

[0105] Next, as shown in FIGS. 6 and 7, the insulating layer 6 of SiO_2 was deposited by atmospheric pressure CVD to be 300 nm, where FIG. 6 is a plan view and FIG. 7 is a fragmentary cross-section view of FIG. 6 along the line A-A'. Then, as the base 7a of the electrode structure, Al was deposited by sputtering to have a thickness of 1 μm . Further, as the overhang 7b, Cr was successively deposited also by sputtering to have a thickness of 200 nm.

[0106] Further, as shown in FIGS. 8 to 10, the overhang 7b, the base 7a, and the insulating layer 6 were patterned, where FIG. 8 is a plan view, FIG. 9 is a fragmentary cross-section view of FIG. 8 along the line A-A', and FIG. 10 is a fragmentary cross-section view of FIG. 8 along the line B-B'. More specifically, a resist pattern for the electrode structure was formed by photolithography, Cr was etched with a solution of ceric ammonium nitrate, and Al was subsequently etched with a mixed etching solution of a phosphoric acid, a nitric acid, and an acetic acid. At this point, sufficient overetching for Al made the overhang of Cr on the order of 1 to 2 μm with respect to the base of Al.

[0107] Further, as shown in FIG. 11 to 13, the element isolation structure 8 was formed as an element isolation structure, where FIG. 11 is a plan view, FIG. 12 is a fragmentary cross-section view of FIG. 11 along the line A-A', and FIG. 13 is a fragmentary cross-section view of FIG. 11 along the line B-B'. More specifically, a polyimide was applied to have a thickness of 2 μm , a positive resist layer to serve as the overhang was successively applied to have a thickness of 3 μm , and exposure and development were carried out to obtain the element isolation structure.

[0108] The organic layer 3a including a light-emitting layer was formed by deposition. First, N,N'-bis(m-methylphenyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine (hereinafter, abbreviated to TPD) as a hole injecting layer and a hole transporting layer and tris(8-hydroxyquinoline)aluminum (hereinafter, abbreviated to Alq₃) as a light-emitting layer and an electron transporting layer were deposited while rotating the substrate. At that point, Alq₃ was doped with 5 wt% of rubrene. Further, copper phthalocyanine was successively deposited. The thicknesses of the TPD, the Alq₃, and the copper phthalocyanine were made to be 50 nm, 50 nm, and 50 nm, respectively.

[0109] Then, as the intermediate electrode 4, an ITO (tin-doped indium oxide) was deposited by sputtering to be 10 nm.

[0110] Further, the organic layer 3b including a light-emitting layer was formed by deposition. First, poly(thiophene-2,5-diyl) as a hole injecting layer, 4,4-bis[(1,1,2-triphenyl)ethenyl]biphenyl as a hole transporting layer and a light-emitting layer, and Alq₃ as an electron transporting layer were deposited to be 10 nm, 50 nm, and 10 nm respectively while rotating the substrate.

[0111] After that, without breaking the vacuum, a Mg/Ag (Ag: 10 wt%) alloy was successively deposited by sputtering as the second electrode 5. The film thickness of the alloy was made to be 200 nm. The second electrode was deposited at a pressure of 10 Pa so that the second electrode deposited sufficiently reached the base 7b. In this way, the second electrode was electrically connected to the electrode structure.

[0112] In the obtained constituent element, the ITO thin film serving as the intermediate electrode 4 was electrically floating as shown in FIG. 1. In addition, it was confirmed that the constituent elements in sections sandwiched between the respective electrode structures 7 independently formed a matrix structure. When a predetermined voltage was applied to this constituent element via the ITO that serves as the first electrode and the base 7b of the electrode structure to drive the constituent element with a current density of 10 mA/cm^2 , substantially white light emission that was a mixed luminescent color of luminescence from each constituent element was observed from the substrate side.

[0113] <Example 2> In Example 1, SiO_2 was deposited by atmospheric pressure CVD to be $0.9 \text{ }\mu\text{m}$ as a foundation layer 9 for forming a trench structure 11 over the glass substrate, as shown in FIG. 14. It is to be noted that FIG. 14 is a fragmentary cross-section view of FIG. 8 along the line B-B'. Then, a stripe-shaped resist pattern $145 \text{ }\mu\text{m}$ in line width and $3 \text{ }\mu\text{m}$ in gap width was provided by photolithography, and about $0.9 \text{ }\mu\text{m}$ of the SiO_2 was etched by RIE (Reactive Ion Etching). The etching was carried out under the etching conditions of the RF power being 2 W/cm^2 , $\text{CF}_4 = 80 \text{ sccm}$, and the gas pressure being 100 mTorr (13.3 Pa). Further, etching was carried out under conditions where the resist was also easily etched [RF power: 2 W/cm^2 , $\text{CF}_4/\text{O}_2 = 70/30 \text{ sccm}$, gas pressure: 100 mTorr (13.3 Pa)]. The depth of the trench was made approximately three times the total of the film thicknesses of the organic layers 3a and 3b including light-emitting layers to be deposited later, and the second electrode layer 5. It is to be noted that gaps of the first electrode and current concentration can be prevented when an opening portion of the trench is formed to have a tapered shape.

[0114] Next, as the first electrode 2, an ITO (tin-doped indium oxide) was deposited by sputtering to be 100 nm . In general, sputtering allows for deposition under conditions enhancing step coverage. When the gas pressure and the distance between the sputtering target and the substrate were made to be 0.3 Pa and 120 mm respectively during deposition by sputtering, the ITO was able to be deposited in the trench structure 11. The ITO was patterned by photolithography to be substantially orthogonal to the stripe pattern of the SiO_2 . The etching was carried out with the use of an etching solution that has a mixture ratio of $\text{HCl} : \text{HNO}_3 : \text{H}_2\text{O} = 6 : 1 : 19$. When the resist was separated, a pattern was formed.

[0115] Then, the insulating layer 6 of SiO_2 was deposited by atmospheric pressure CVD to be $0.3 \text{ }\mu\text{m}$. With the RF power being 2 W/cm^2 , $\text{CF}_4/\text{O}_2 = 70/30 \text{ sccm}$, and the gas pressure being 100 mTorr (13.3 Pa), etching was carried out by RIE, and the resist was separated to obtain an insulating layer as shown in FIG. 14.

[0116] With the exception described above, the organic layers 3a and 3b and the intermediate electrode 4 were formed in the same way as in Example 1, and a Mg/Ag alloy (weight ratio: 10 : 1) was deposited as the second electrode. The film thickness of the alloy was made to be 200 nm. The second electrode was obliquely deposited in a direction substantially orthogonal to the direction in which the trench extends, without rotating the substrate so that the trench portion was not completely covered. The second electrode 6 was formed to be separated in a stripe shape with the trench structure 11 interposed.

[0117] When the obtained organic EL display device was evaluated in the same way as in Example 1, about the same result as that in Example 1 was obtained.

[0118] <Example 3> In Example 1, after forming the electrode structure 7, a positive resist was applied to be 2 μm and dried as shown in FIGS. 15 and 16, where FIG. 15 is a fragmentary cross-section view of FIG. 8 along the line A-A', and FIG. 16 is a fragmentary cross-section view of FIG. 8 along the line B-B'. Further, as shown in FIGS. 15 and 16, exposure was carried out in a direction 21 perpendicular to the surface of the substrate and a direction 22 substantially orthogonal to the direction in which the electrode structure extends. Then, when the resist was developed, an insulating film composed of a resist material 12 was formed on only an unexposed portion of the base 7b of the electrode structure 7 as shown in FIG. 17 and 18.

[0119] With the exception described above, the organic layers 3a and 3b and the intermediate electrode 4 were formed in the same way as in Example 1, and a Mg/Ag alloy (weight ratio: 10 : 1) was deposited as the second electrode. The film thickness of the alloy was made to be 200 nm. The second electrode was obliquely deposited in a direction substantially perpendicular to the direction in which the electrode structure 7 extends to be deposited also on a shade portion of one electrode structure 7, without rotating the substrate so that the trench portion was not completely covered. The second electrode 6 was formed to be separated by the insulating film of the electrode structure.

[0120] When the obtained organic EL display device was evaluated in the same way as in Example 1, about the same result as that in Example 1 was obtained.

[0121] <Example 4> In Example 1, after forming the electrode structure 7, a SOG (spin-on-glass) film was deposited to be 50 nm as an insulating film 13 as shown in FIGS. 19 and 20, where FIG. 19 is a fragmentary cross-section view of FIG. 8 along the line A-A', and FIG. 20 is a fragmentary cross-section view of FIG. 8 along the line B-B'. Then, a positive resist was applied to be 2 μm and dried as shown in FIGS. 21 and 22, where FIG. 21 is a fragmentary cross-section view of FIG. 8 along the line A-A', and

FIG. 22 is a fragmentary cross-section view of FIG. 8 along the line B-B'. Further, as shown in FIGS. 21 and 22, a photomask 26 was arranged over the substrate, and mask exposure 25 was carried out in a direction perpendicular to the surface of the substrate. Further, the resist was developed, and the SiO₂ was etched. The etching of the SiO₂ was carried out by treating for 10 seconds with a commercially available hydrofluoric acid solution diluted with water to 1/20.

[0122] When the resist material was removed after the etching, the insulating film 13 of SiO₂ was formed only in the exposed portion as shown in FIGS. 23 to 25, where FIG. 23 is a plan view, FIG. 24 is a fragmentary cross-section view of FIG. 23 along the line A-A', and FIG. 25 is a fragmentary cross-section view of FIG. 23 along the line B-B'.

[0123] With the exception described above, an organic EL display device was obtained in the same way as in Example 1. When the obtained organic EL display device was evaluated in the same way as in Example 1, about the same result as that in Example 1 was obtained.

[0124] As is clear from the results described above, the present invention makes it possible to obtain an organic EL display device that has a multilayer structure (has a plurality of light-emitting layers) according to a relatively simple process.

[0125]

[Effect of the Invention] As described above, according to the present invention, it is possible to achieve an organic EL display device that can be manufactured with more flexibility, further allows for obtaining a wide emission wavelength range, requires a small number of wirings and a simple manufacturing process even when a complex stack structure is used such as a color display, and also allows for obtaining high luminance, and a manufacturing method thereof.

[Brief Description of the Drawings]

[FIG. 1] a schematic cross-section view illustrating the fundamental structure of an organic EL display device of the present invention

[FIG. 2] a circuit diagram illustrating how each constituent unit of a conventional organic EL display device is connected

[FIG. 3] a circuit diagram illustrating how each constituent unit of an organic EL display device of the present invention is connected

[FIG. 4] a plan view illustrating a manufacturing process for an organic EL display device, which is an example of the present invention, where a first electrode is formed

[FIG. 5] a fragmentary cross-section view of FIG. 4 along the line A-A' illustrating the manufacturing process for an organic EL display device as the example of the present invention

[FIG. 6] a plan view illustrating the manufacturing process for an organic EL display device, which is an example of the present invention, where layers corresponding to a base and an overhang of an electrode structure are formed

[FIG. 7] a fragmentary cross-section view of FIG. 6 along the line A-A' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention

[FIG. 8] a plan view illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where the base and overhang of the electrode are patterned, and an insulating layer is patterned.

[FIG. 9] a fragmentary cross-section view of FIG. 8 along the line A-A' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention

[FIG. 10] a fragmentary cross-section view of FIG. 8 along the line B-B' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention

[FIG. 11] a plan view illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where an element isolation structure is formed after the formation of the electrode structure

[FIG. 12] a fragmentary cross-section view of FIG. 11 along the line A-A' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention

[FIG. 13] a fragmentary cross-section view of FIG. 11 along the line B-B' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention

[FIG. 14] a cross-section view illustrating a manufacturing process for an organic EL display device, which is an example of the present invention, where a trench structure is formed as an element isolation structure, and an electrode structure is formed

[FIG. 15] a fragmentary cross-section view of FIG. 8 along the line A-A' illustrating a manufacturing process for an organic EL display device, which is an example of the present invention, where a photoresist layer is formed after the formation of the electrode structure

[FIG. 16] a fragmentary cross-section view of FIG. 8 along the line B-B' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where the photoresist layer is formed after the formation of the electrode structure

[FIG. 17] a fragmentary cross-section view of FIG. 8 along the line A-A' illustrating the

manufacturing process for an organic EL display device, which is the example of the present invention, where the photoresist layer is developed after the formation of the photoresist layer

[FIG. 18] a fragmentary cross-section view of FIG. 8 along the line B-B' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where the photoresist layer is developed after the formation of the photoresist layer

[FIG. 19] a fragmentary cross-section view of FIG. 8 along the line A-A' illustrating a manufacturing process for an organic EL display device, which is an example of the present invention, where an insulating film is formed after the formation of the electrode structure

[FIG. 20] a fragmentary cross-section view of FIG. 8 along the line B-B' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where the insulating film is formed after the formation of the electrode structure

[FIG. 21] a fragmentary cross-section view of FIG. 8 along the line A-A' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where the insulating film is formed, and a photoresist layer is further formed and exposed

[FIG. 22] a fragmentary cross-section view of FIG. 8 along the line B-B' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where the insulating film is formed, and the photoresist layer is further formed and exposed

[FIG. 23] a plan view illustrating the manufacturing process for an organic EL display device, which is the example of the present invention, where development is carried out after the exposure

[FIG. 24] a fragmentary cross-section view of FIG. 23 along the line A-A' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention

[FIG. 25] a fragmentary cross-section view of FIG. 23 along the line B-B' illustrating the manufacturing process for an organic EL display device, which is the example of the present invention

[FIG. 26] a cross-section view illustrating an example of a conventional organic EL display device

[Explanation of the Reference Numerals and Signs]

1 substrate

- 2 first electrode
- 3a, 3b organic layers
- 4 intermediate electrode
- 5 second electrode
- 6 insulating layer
- 7 electrode structure